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THE USE OF SULFUR DIOXIDE IN SHIPPING GRAPES

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An investigation conducted by the Division of Viticulture, University of California, in 1923–24 resulted in the development of a useful method of treating fresh grapes with sulfur dioxide. The purpose of the treatment is to delay the deterioration caused by the development of molds and other decay-causing organisms in the grapes during transit or storage. It was successfully applied to commercial practice in the fall of 1924 and its use has developed to such an extent that in 1928 between 10,000 and 15,000 carloads of grapes were treated by this method or a modification of it.

Numerous inquiries for information concerning the treatment have been received by the College of Agriculture and the aim of this circular is to supply growers and shippers of fresh grapes with the best information available at the present time.

PROPERTIES OF SULFUR DIOXIDE

Sulfur dioxide, produced by burning sulfur, is a gas at ordinary temperatures and atmospheric pressure, 2.2 times as heavy as air. It is colorless and has a very pungent, irritating odor. By pressure it can be condensed into a clear, water-white liquid which appears in commerce in steel cylinders.

Its preservative properties have long been recognized and it is extensively used as a preservative and bleaching agent in the dried fruit industry, where it is produced by burning sulfur in "sulfuring" rooms. It is very toxic to molds and bacteria and when present, even in very low concentration, represses the development of these organisms. Table 1 shows the effect of small amounts of sulfur dioxide on the multiplication of such organisms in grape juice.

It is a strong bleaching agent and will decolorize grapes if applied to them in amounts greater than that necessary to repress the development of decay-causing organisms, although the color again returns

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when the sulfur dioxide is removed by evaporation or otherwise. When present in sufficient concentrations to decolorize the grapes, sulfur dioxide also injures their taste and texture, making them unfit for table use.

TABLE 1*

NUMBER OF LIVING CELLS PER CUBIC CENTIMETER AFTER 36 HOURS EXPOSURE TO VARIOUS CONCENTRATIONS

Organism‡	Number of cells per cubic centimeter at start	Concentrations of sulfur dioxide in parts per million			
		50	100	200	400
Wine yeast	20,000	640,000	2,000,000	310,000	36,000
Apiculatus	150,000	200,000	75,000	56,000	0
Wild yeast (Pastorianus form)	620,000	580,000	6,000	190	0
Penicillium	120,000	40,000	0	0	0
Aspergillus	450,000	120,000	20,000	30,000	0
Vinegar bacteria	310,000	14,000	300	2	0

* CRUESS, W. V. The effect of H_2SO_3 on fermentation organisms. Jour. Ind. and Eng. Chem., **4**: 581–585. 1912.

‡ All of these organisms except the wine yeast were isolated from California grapes.

TABLE 2

THE EFFECTS OF DIFFERENT AMOUNTS OF SO_2* ON KEEPING QUALITY, COLOR, FLAVOR, AND TASTE OF GRAPES

Variety	Parts per million of SO_2 added to grapes	Color and texture of the treated grapes	Days elapsing before spoiling‡	Effect of the SO_2 on flavor
Black Prince	0 (check)	Normal	7 days	
	64	Normal	16 days	Flavor normal
Malaga	0 (check)	Normal	8 days	
	35	Normal	14 days	Flavor normal
	92	Normal	16 days	Flavor normal
	201	Normal	20 days	Flat and with trace of SO_2
Hunisa	0 (check)	Normal	8 days	
	19	Normal	11 days	Flavor normal
	38	Normal	14 days	Flavor normal
	185	Color bleached and texture somewhat softened	20 days	Taste slightly injured
Ohanez	0 (check)	Normal	10 days	
	13	Normal	16 days	Flavor normal
	43	Normal	22 days	Flavor normal
	125	Normal	30 days	Taste almost normal after 30 days

* SO_2 is the symbol used by chemists for sulfur dioxide.

‡ The grapes were stored at ordinary room temperature at Davis. They were considered spoiled when 15 per cent or more of the berries were moldy or decayed.

QUANTITY OF SULFUR DIOXIDE NECESSARY

By careful experimentation[2] it has been found that a concentration in the grapes of 50 parts of sulfur dioxide per million parts of grapes (0.005 per cent) will delay the development of molds and other decay organisms so that the rate of deterioration is approximately one-half that of similar untreated grapes stored under similar conditions. Concentrations of less than 50 parts per million are less effective although it appears that any measurable quantity present has some effect. Above 50 parts per million the effectiveness increases slightly with an increase in concentration. With concentrations of more than 100 parts per million the color, texture, and flavor of the grapes may be injuriously affected. The figures and notes in table 2 illustrate these points.

In view of these data, it appears that the correct concentration *in the grapes* is between 50 and 100 parts per million. These limits have proved safe and practicable although suitable equipment and careful and intelligent operation are necessary to stay within them. It is probably a good practice to keep in the lower rather than the upper part of this range.

FUNDAMENTAL PRINCIPLES OF THE PROCESS

The general principle of treatment as it was worked out by the Division of Viticulture consists in surrounding the grapes with an atmosphere of air containing from 1.8 to 3.0 per cent (by volume) of cool sulfur dioxide. The grapes absorb the sulfur dioxide from this dilute mixture at a relatively slow rate. The amount absorbed by the grapes is regulated by the concentration of the gas in the atmosphere, and the time of exposure.

In commercial practice at the present time, the concentration of sulfur dioxide in the atmosphere of the car[3] (or other treating chamber) is made uniform by rapidly displacing the original air in the car with the sulfur-dioxide—air mixture. When the displacement is practically complete the car is closed and the grapes allowed to absorb the sulfur dioxide.

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[2] Winkler, A. J. and H. E. Jacob. The utilization of sulfur dioxide in the marketing of grapes. Hilgardia, 1:107–131. 1925.

[3] By far the greatest proportion of the grapes treated at the present time are treated after being loaded into refrigerated railroad cars. Hence the term "car" will be commonly used in this circular instead of "treating chamber."

The mixture of air and sulfur dioxide is made outside of the car, either by vaporizing and diluting commercial liquid sulfur dioxide or by burning sulfur in a special generator. If the source of the sulfur dioxide is liquid material, it is cool as it comes from the vaporizer and after being properly diluted with air, is forced directly into the car. Two types of apparatus using liquid as the source of the sulfur dioxide are described later in this circular. If sulfur is burned to produce the sulfur dioxide, the gas as it comes from the generator is hot and must be cooled before being applied to the grapes to avoid serious damage to the fruit with which it first comes in contact. It has been found most practicable to cool the hot gas by passing it through water-cooled tubes. By these methods fairly uniform absorption is obtained in all parts of an ordinary refrigerated car loaded in the usual manner with grapes packed in ordinary lugs or crates *but not in sawdust or other filler material.*

Statements made in this circular apply only to those methods of application involving the principle outlined above. Many other schemes of applying the sulfur dioxide to the grapes were tried in the original experiments and some have been tried in experiments by shippers on a semi-commercial scale. None, however, have given satisfactory results. Burning sulfur in open pans inside of the closed cars has been repeatedly tried. *No data are anywhere on record showing that consistently good results can be obtained by this method and it is not to be recommended.*

It is not improbable that a method of releasing the sulfur dioxide inside of the car and distributing it so that the grapes are uniformly treated will be perfected at some future time. At present, however, no adequate means of doing this has been discovered.

THE ABSORPTION OF SULFUR DIOXIDE BY GRAPES

The amount of sulfur dioxide absorbed by the grapes is influenced by a number of factors, the most important of which are the concentration of sulfur dioxide in the atmosphere, the time of exposure, and the temperature, maturity, and physical condition of the grapes.

Concentration of Sulfur Dioxide in the Atmosphere and the Time of Exposure.—Grapes slowly absorb sulfur dioxide from very dilute mixtures. As the concentration of gas is increased the rate of absorption is also increased. Doubling the concentration of gas more than doubles the amount absorbed by the grapes in a given length of time. For practical use, an initial concentration of 1.8 to 3.0 per cent

(by volume) is convenient. If a concentration of 2 per cent is maintained, 50 to 100 parts per million will be absorbed by average grapes of most vinifera varieties in about 20 minutes. With a 3 per cent concentration a similar amount will be absorbed in about 10 minutes.

The apparatuses described on pages 9–17 will practically displace the air in an ordinary refrigerated car, loaded with grapes, in about 10 minutes. Hence, a concentration of less than 3 per cent must be used if the grapes are expected to absorb uniformly not more than 100 parts per million. Under most conditions, if the air in the car

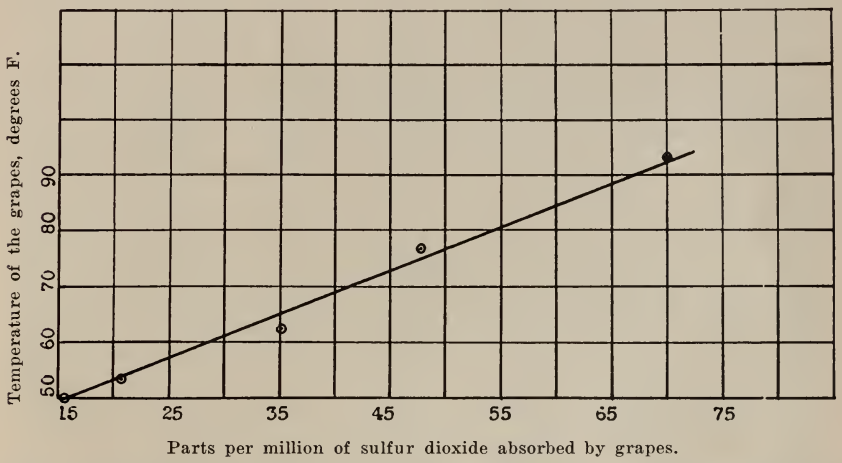


Fig. 1.—The influence of the temperature of the grapes on the rate of absorption of sulfur dioxide.

is displaced within 10 minutes by a 2 per cent mixture and the car then closed, a satisfactory treatment is obtained. The sulfur dioxide in the atmosphere in the car is taken up by the grapes, by the wood in the car, and by the ice in the bunkers so that within an hour it has practically all disappeared from the air within the car. If a 2 per cent concentration is used there are approximately 5 pounds of sulfur dioxide in the car when it is closed. Not more than 3 pounds of it is absorbed by the grapes. The remainder is taken up by the melting ice and the wood in the car.

Temperature.—Warm grapes absorb sulfur dioxide more rapidly than cold grapes. The chart shown in figure 1 gives an idea of the influence of temperature. From this chart it can be seen that at 94 degrees (Fahrenheit) the rate of absorption was practically twice as fast as at 62° F. While not nearly so important a factor as the

concentration of gas in the atmosphere, the temperature of the grapes must be taken into consideration in order to obtain uniform results throughout the season. A higher concentration (or a longer exposure obtained by increasing the time during which the diluted gas flows through the car) is necessary with cold than with warm grapes.

Maturity of the Grapes.—Green grapes absorb sulfur dioxide more rapidly than ripe grapes. Treated for 7 minutes with a mixture of 4 per cent sulfur dioxide in air, Muscat grapes of 13° Balling absorbed 262 parts per million of sulfur dioxide; those of 18° absorbed 77 parts, and those of 27° absorbed 43 parts. Cipro Nero grapes of 10° Balling absorbed 218 parts; those of 17° absorbed 129 parts; and those of 23° absorbed 110 parts.

The very green grapes used in this test were, of course, greener than would ever be encountered in commercial practice. The green and ripe classes are, however, within the range of maturity of grapes of commerce. Very ripe grapes should therefore be treated with a slightly higher concentration (or a slightly longer exposure) than green grapes.

TABLE 3

THE INFLUENCE OF PHYSICAL CONDITION (SOUNDNESS) OF THE GRAPES ON THE RATE AT WHICH SO_2 IS ABSORBED

Variety	Condition of berries	Parts per million of SO_2 absorbed from a 2 to 3 per cent gas mixture		
		In 10 minutes	In 20 minutes	In 30 minutes
Muscat	Sound	60	85	114
	Stemmed	121	154	211
Tokay	Sound	58	64	93
	Stemmed	105	144	200

Physical Condition of the Grapes.—Grapes which are broken, bruised, wet, moldy, or even just "weak" in general constitution due to poor nutrition while they were maturing on the vine, absorb sulfur dioxide more rapidly than physically sound grapes. Varieties which have soft texture or thin skins show a tendency to absorb it more rapidly than firm-textured varieties with thick skins. An idea of the effect of the condition of the grapes on the rate of absorption can be obtained from table 3 which gives the results of a test in which Tokay and Muscat berries were carefully stemmed in such a way as to confine the extent of the injury to the removal of the stems.

The figures of table 3 show that the stemmed berries absorbed sulfur dioxide approximately twice as rapidly as the sound berries.

This greater rate of absorption by unsound fruit is a fortunate circumstance. Decay usually starts first in the injured berries and then spreads to the sound fruit. The arrest of decay in the injured berries by the relatively large quantity of sulfur dioxide absorbed by them largely removes the danger of premature spoiling of the sound grapes which contain less of the preservative. The manner of treatment should not usually be modified to compensate for the differences in the rate of absorption of sound and unsound fruit. In general, fruit that absorbs sulfur dioxide slowly would keep well without it and that which absorbs it rapidly would spoil quickly without it.

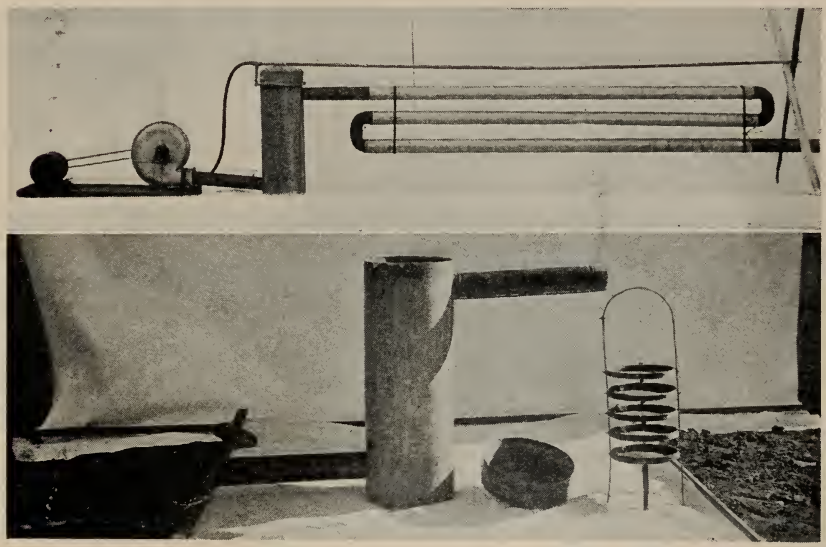


Fig. 2.—A sulfur-burning apparatus for generating sulfur dioxide and applying it to fresh grapes. Upper, the entire apparatus assembled. Lower, the stove disassembled to show the details of construction.

EQUIPMENT FOR APPLYING SULFUR DIOXIDE TO GRAPES

Three different styles of apparatus have been developed and used commercially to produce the sulfur-dioxide–air mixture and apply it to the grapes. They differ only in the way in which they produce the proper mixture of sulfur dioxide and air and force it into the car. The general principle of application is the same for all and conforms strictly to what has been said on preceding pages. All three have proved practicable but each has certain merits not possessed by the others. One produces the sulfur dioxide by burning sulfur and the other two utilize commercial liquid sulfur dioxide as the source of the gas.

Sulfur-burning Apparatus.—A type of equipment which burns sulfur was used in the original experimental work in 1923–24. Several commercial outfits, having sufficient capacity to treat carloads, have been built and used on a limited scale.

A good grade of pure sublimed sulfur is burned under forced draft in a specially constructed stove which is adjusted so that the gases coming from the stove contain about 2 per cent sulfur dioxide. The hot gas from the stove is led through a gas cooler and then directly into the car. Power and running water are essential for its operation. A photograph of such an apparatus is shown in figure 2.

The sulfur is placed in shallow pans which are supported, one above the other, in an iron rack which in turn fits the inside of the stove. For a full car of grapes about seven pounds of sulfur is divided equally among the several pans. This quantity of sulfur will produce fourteen pounds of sulfur dioxide. The number of pans used depends upon the concentration of gas desired. In fact the concentration of the gas is regulated by varying the number of pans. In the generator shown in figure 2, five pans were needed to produce a 2 per cent concentration. The sulfur on each pan is ignited before the rack carrying the pans is inserted in the stove. With the sulfur burning, the rack is placed in the shell and the lid placed in position. The blower is then quickly started (before the sulfur has a chance to stop burning owing to the exhaustion of the oxygen in the stove) and the water turned on to cool the gas cooler and the stove.

The sulfur burns very vigorously under the forced draft. The heat from the lower pans helps to vaporize the sulfur in the upper pans and the entire charge of sulfur is burned in from 12 to 15 minutes. A great amount of heat is generated by the rapid burning of the sulfur and it is necessary that the stove as well as the gas cooler be cooled with running water. If the stove is not kept cool the rate of burning increases as the stove gets hotter, and it becomes impossible to maintain a uniform concentration of sulfur dioxide in the gases from the stove. Furthermore, when the stove gets very hot much of the sulfur sublimes, and does not burn, owing to insufficient oxygen. The sulfur vapor then condenses to a fine yellow powder in the gas cooler and is blown into the car and onto the grapes.

Specifications of materials are here given that were used in constructing the sulphur dioxide generator used by the Division of Viticulture, University Farm, Davis, for demonstrating the treatment of carloads of grapes with sulfur dioxide (see figure 2).

Motor and blower assembly:

Motor—1 horse-power electric single phase induction motor, 1760 r.p.m.; size of pulley 3″.

Blower—From Niagara Orchard Duster, model F 23. Rotor about 12″ diameter; discharge 4″ diameter; size of pulley 2¼″. Motor and blower mounted as shown in figure 2. Blower driven by belt from motor, at a speed of 2250 r.p.m. Delivery of blower is 450 cu. ft. per minute with no resistance beyond outlet; 300 cu. ft. per minute through SO_2 generator and cooling coil.

Stove:

Shell—Cut from an old pressure water tank, 14″ in diameter. This was cut 3′ from the bottom of the tank.

The air inlet to the stove to receive the discharge from the blower was cut with an acetylene torch, and then dressed so as to make a tight joint with a 4″ stovepipe. It was about 1″ from the bottom (inside) of the stove.

A similar hole for the outlet of the stove was cut 4″ from the top of the stove and on the opposite side.

Lid—Top section of the same water tank 14″ in diameter and 4″ high. Hammered so as to "bell" out and slip over the bottom section of stove, making a nearly air-tight joint.

Burner—

(*a*) Framework made from 3/16″ × ¾″ wrought iron.
Pieces cut and drilled with 7/32″ holes as follows:
4 pieces 32″ long drilled at ½″, 8¼″, 16″, 31½″.
1 piece 32″ long drilled at ½″, 8¼″, 16″, 23¾″, 31½″.
Each of these 5 pieces was bent into a circle and form the immediate supports for the pans, the one with 5 holes being used at the bottom, the fifth hole being for the attachment of the short leg.
1 piece 41″ long drilled at 7″, 10″, 13″, 16″, 19″, 40″ } two legs and
1 piece 27″ long drilled at 7″, 10″, 13″, 16″, 19″, 27″ } handle.
1 piece 20″ long drilled at 7″, 10″, 13″, 16″, 19″, third leg supporting pan rings.
1 piece 8″ long drilled at 7″, fourth leg attached to bottom ring.
These pieces were fastened together in the manner shown in figure 2 with 3/16″ × ¾″ stove bolts. 17 bolts were used.

(*b*) Pans—Five 10″ cake pans, inside diameter 9½″, depth 1″, sides perpendicular to bottom, bottoms solid.

Gas cooler and water pipe:

1 joint 4″ stove pipe, crimped at both ends.
3 10′ joints galvanized iron conductor pipe.
4 4″ elbows.
2 pieces 3/16″ × ¾″ × 32″ wrought iron, drilled with 7/32″ hole ½″ from ends. (Used to hold cooling coil together as shown in photograph.)
14′ of ¾″ galvanized pipe drilled in straight line and at every 2″ with 3/32″ hole.

3½′ of ½″ galvanized pipe drilled in straight line and at every 4″ with 3/32″ hole. (This is bent into a circle, with the holes inside and slightly downward to encircle and cool the stove.)
1 tee, galvanized, ¾″.
1 ¾″ to ½″ bushing.
1 ½″ × 5″ galvanized nipple.
1 ½″ galvanized elbow.
1 ¾″ galvanized cap.
1 ½″ galvanized cap.
1 pipe thread to hose-coupling thread bushing. These parts were assembled as shown in the photograph. The holes in the ¾″ pipe are downward and water from this pipe drips over the 4″ coil and cools the gas from the stove.

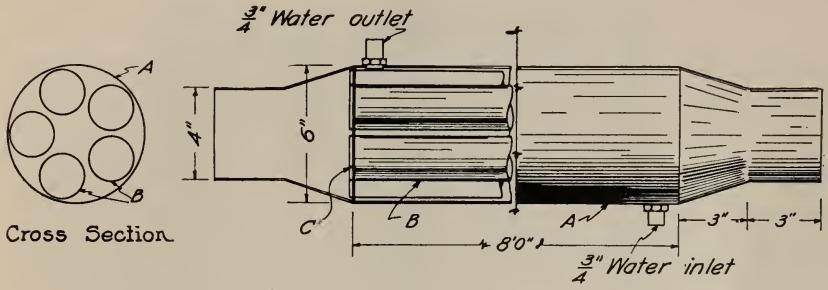
Other 4″ pipe and fittings are required to make connections with the car. These vary with each location, but should under all circumstances be as short and straight as is possible.

Since this outfit was constructed, some improvements have been suggested. A motor-blower assembly capable of delivering approximately 300 cubic feet of air per minute through the apparatus can now be purchased. It consists of a ½ h.p. 3600 r.p.m. constant speed electric motor direct connected to a blower 12 inches in diameter. This is the assembly now used with the apparatus shown in figure 7.

The cumbersome coil cooler of the original equipment can easily be replaced by the more efficient tubular cooler shown in figure 3. This consists of five 2-inch galvanized iron conductor pipes inside of a 6-inch pipe. The ends of the 2-inch pipes are soldered into diaphragms in the 6-inch pipe at both ends. Both ends of the cooler beyond the diaphragms are reduced to 4 inches to allow connections to be made with the stove on one end and a 4-inch conductor pipe to the car on the other end. A water inlet, accommodating the fitting at the end of a ¾-inch hose, is inserted at one end and an outlet to which a similar hose can be attached is inserted at the other end and on the opposite side of the 6-inch water jacket. When being used, the water outlet end should be nearest the stove so that the water and gas flow in reverse directions and maximum cooling of the gas is obtained and so that the water from the cooler can be most conveniently used for cooling the stove. The outlet should also be on top and the inlet below while the equipment is being used. The hot gases from the stove pass through the 2-inch pipes, which are surrounded with cold water, and are thus cooled.

This sulfur burning apparatus will do good work at small cost where power (preferably electricity) and running water are available. The equipment, except the sulfur pans which can be replaced at small

cost, is durable and with ordinary care should last for several years. The work can probably be more cheaply done with this apparatus than with any other. However, very careful attention to detail of construction is essential, and cannot be over-emphasized. The parts used in the construction of the stove must conform exactly to the specifications given unless means are at hand to analyze the gas produced and make necessary adjustments so a mixture of approximately 2 per cent by volume of sulfur dioxide is produced.



A - Galv. iron water jacket. B - 2" Gas tubes. C - End water seal

Fig. 3.—An improved tubular cooler for cooling the hot gases from the sulfur dioxide generator.

If the specifications for the construction of the stove are rigidly followed and the blower delivers 300 cubic feet of air per minute through the entire apparatus, and if on a test run 6 to 7 pounds of sulfur are burned in between 12 and 15 minutes and the gas as it comes from the gas cooler is cool, it may be assumed that everything is satisfactory. However, even then it is best to make a test run using only a few boxes of grapes and exposing them for 20 minutes to the gas coming from the stove. The grapes should remain undamaged, should show about 50 parts per million of sulfur dioxide by chemical analysis, and should keep about twice as long as untreated grapes.

A false door which fits the opening of one side door, through which the conductor pipe from the apparatus can be inserted into the car, is necessary. The type of door commonly used consists of a wooden frame covered with heavy canvas. The sides and one end are heavily padded to make the door fit snugly. The overall width should be the same as the width of a single side door of the car. Since the height of the car doors varies, one end of the false door should be adjustable so that the door can be lengthened or shortened. The adjustable end

should be used as the bottom for sake of convenience in adjusting it. A hole through the canvas to accommodate the 4-inch conductor pipe is made just above the adjustable end. A photograph of such a door is shown in figure 4.

Brief directions for operating are as follows: The stove should be set up and the blower connected with the air inlet at the bottom. One end of the gas cooler is connected with the outlet of the stove and the other end to a false door in the car. All connections should

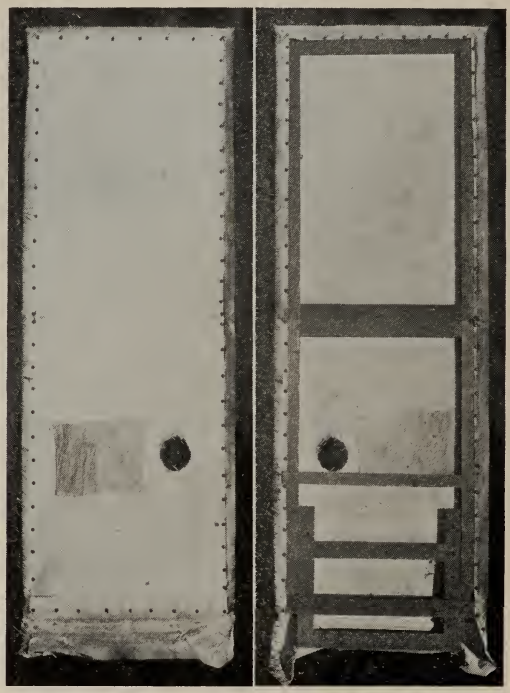


Fig. 4.—A false car door through which a conductor pipe may be inserted into the car. Left, outside view of the door. Right, inside view of the door showing the construction of the adjustable end.

be as short and straight as possible. Water connections are made, and tested. The ventilators on the top of the car at both ends are opened and the plugs removed (any other treating chamber must be provided with ventilators at the top of the room).

The quantity of sulfur to be burned is divided equally among the pans used. The loaded pans are placed in the iron support and the sulfur on every pan is ignited. When the sulfur is burning freely the entire burner is inserted in the stove and the lid placed in position. The blower is quickly started (before the sulfur has a chance

to stop burning owning to the exhaustion of the oxygen in the stove) and the water turned on to cool the condenser and the stove.

When the sulfur is burned out, as shown by the more or less sudden cooling of the stove, the blower is stopped, the outfit disconnected from the car, the false door removed, and the doors and ventilators of the car closed tight.

Machines Using Liquid Sulfur Dioxide.—The sulfur-burning apparatus is cumbersome and requires both power and water for its operation. Furthermore, it cannot at present be purchased entire but must be constructed from parts obtained from miscellaneous

Fig. 5.—A machine for vaporizing liquid sulfur dioxide and diluting it with air. This machine is described in the text as Type 1. (Courtesy, W. E. Lawson.)

sources. Insurance companies also object to the use of the sulfur burner inside of packing houses because of the fire hazard involved. To overcome these difficulties, two types of equipment have been perfected which make use of commercial liquid sulfur dioxide. The liquid is vaporized and diluted with air to the proper concentration and then forced into the car. For the purpose of discussion and description these two types of apparatus will be designated as Type 1 and Type 2.

Type 1: The sulfur dioxide is vaporized by placing the cylinder containing it in a water bath. The heat is supplied by a gasoline stove beneath the water bath. The gas which is under pressure in

the cylinder is released by means of control valves, through a special mixer. The mixer is so constructed that the flow of gas through the mixer creates a suction which draws in the air to dilute the gas. The energy of the expanding gas is sufficient to draw the necessary quantity of air for proper dilution through the mixer and to force the resultant mixture of air and sulfur dioxide into the car.

A photograph of this equipment is shown in figure 5. This apparatus is patented and cannot be used without the approval of the owners of the patent rights.[4] The machine is compact and eliminates the necessity of power and running water. It does not, however, entirely eliminate the hazard of fire for the gasoline stove or some other source of heat is necessary for its operation.

Since this apparatus cannot be used except under the supervision of the patentee, a detailed set of directions for its operation is not necessary in this circular. These directions are furnished with the machine.

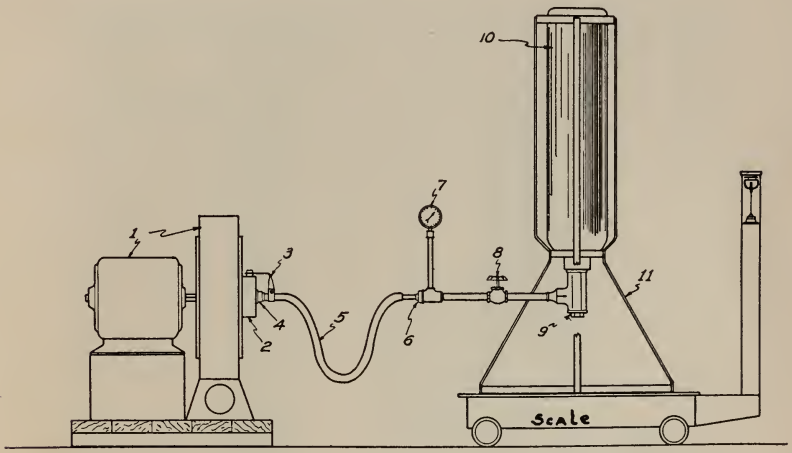
Type 2:[5] This machine is an outgrowth of an assembly used in the original work for vaporizing and diluting the liquid sulfur dioxide. The liquid is sprayed into a motor driven blower, where it is vaporized by the heat of the air which is drown through the blower to dilute the sulfur dioxide. The diluted gas is then blown into the car containing the grapes to be treated. The machine was adapted to commercial use in 1928 through the cooperation of the California Fruit Exchange and has proved reliable and efficient. It now can be purchased in completely assembled form.

Figure 6 shows a diagrammatic sketch of this machine and figure 7 a photograph of the complete assembly. It consists of a direct connected electric motor-blower (*1*). This is a ½ h.p., 3600 r.p.m., constant speed electric motor, with the rotor of a blower 12 inches in diameter mounted on the motor shaft. The intake of the blower is 3¾ inches inside diameter, and the discharge is 3¼ inches inside diameter. The intake baffle plate (*2*) is used to adjust the air flow to the desired quantity (approximately 300 cubic feet per minute). The nozzle (*4*) is held rigidly in place by the support (*3*). This nozzle is of the whirling spray type with an orifice of 0.040 inches. The disc of the nozzle is of non-corrosive stainless steel. A flexible tube (*5*) connects the nozzle with the supply of sulfur dioxide. A fine mesh screen (*6*) is inserted in the conductor line to catch any

[4] The patent rights of this apparatus are controlled by the Esotoo Fumigation Company, Rutherford, California.

[5] A public Service patent on this equipment has been applied for by the University of California.

solid particles, like scale, which might clog the nozzle orifice. A pressure guage (*7*) between the control valve and the nozzle is necessary in order to maintain a uniform flow through the nozzle. The control valve (*8*) is used to adjust the flow of liquid to the proper quantity. The cylinder valve (*9*) is a part of the cylinder (*10*) containing the supply of liquid sulfur dioxide. The cylinder support (*11*) holds the cylinder in an inverted position so that the liquid can be drawn off. The platform scale is necessary to weigh out the quantity of sulfur dioxide desired for each treatment.



1 Motor blower assembly.
2 Baffle plate
3 Nozzle support
4 Nozzle
5 Flexible tube
6 Screen
7 Pressure guage
8 Control valve
9 Cylinder valve
10 Cylinder, containing SO_2
11 Cylinder support

Fig. 6.—A diagram of a machine using a motor driven blower to vaporize and dilute liquid sulfur dioxide. This machine is described in the text as Type 2.

DIRECTIONS FOR OPERATING THE TYPE 2 LIQUID-USING APPARATUS

These machines are presumably all tested at the factory, but before attempting to treat a carload of grapes, a test run should be made by the individual who will operate the machine so that he may become familiar with its operation and thus reduce the probability of making a mistake. The regulation of the flow of sulfur dioxide may also need to be modified.

The test run should be made as follows: Place the machine on a platform scale which is sensitive to less than ¼ pound and which

will weigh the machine with a full cylinder of sulfur dioxide in place in the cylinder support. Place the entire outfit in a location where the gas may be discharged into the air and not be blown back to the machine nor in the direction of anyone who might be near enough to be affected by it. Connect the discharge pipe to the blower and be sure that it is supported at one point only so that it does not interfere with the action of the scale. The point of support for the discharge pipe should be near the end farthest away from the blower.

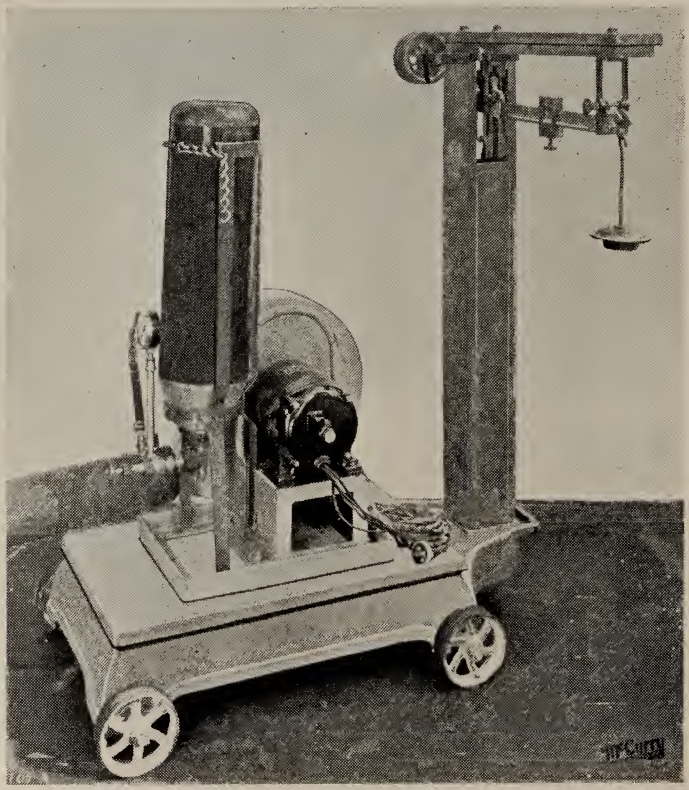


Fig. 7.—A photograph of the Type 2 machine to vaporize and dilute liquid sulfur dioxide. (Courtesy, The Blue Anchor.)

The end attached to the blower is supported by the blower which, in the case of the factory-made machine, is placed on the scale. Make the necessary electrical connections from the power line to the motor and turn on the power. Close the control valve and open the valve on the cylinder. Balance the scale very carefully. After it is balanced place a one-pound weight on the platform of the scale. The scale is now exactly one pound out of balance. Open the control valve

and note, on a watch or clock which registers seconds, the exact time. Regulate the control valve so that the pressure on the gauge remains constant at the point recommended by the manufacturers (usually 15 pounds). Allow the sulfur dioxide to flow until the scale again comes exactly to balance. Note the time and close the control valve. One pound of gas has been run out and this should require just one minute. If the scale comes to balance in less than one minute, remove the one-pound weight and again balance the scale. Replace the weight, note the time and again open the control valve but regulate it so that the pressure registered on the gauge is somewhat less than it was during the previous trial. Again note the time required for the scale to come to balance. Repeat this procedure until the pressure is determined which is necessary to force one pound of liquid per minute through the nozzle. If more than one minute is required for the first pound of gas to run out, obviously the pressure should be increased instead of decreased for succeeding tests.

These machines are adjusted so that a flow of one pound per minute of sulfur dioxide through the nozzle, results in approximately a 2 per cent (by volume) mixture. This is the best concentration to use for most grape treatments. Suggestions for modification of this concentration under exceptional conditions are given under the heading "Suggestions and Cautions."

The procedure for treating a car loaded with grapes is as follows:

1. *Open the ventilators at both ends on top of the car and take out the plugs.* This is of utmost importance and failure to do so is almost certain to result in overdosing the grapes at the center of the car.

2. Open one door—on the side of the car where the machine is to be used. This should be on the windward side if possible. Place the false door in position and see that it fits tight.

3. Place the machine on a platform scale directly in front of the false door and insert the end of the discharge pipe through the opening in the false door. The end of the discharge pipe must not be obstructed by the car bracing nor anything else. It need not extend more than a few inches through the false door.

4. Make the necessary electric connections and turn on the power.

5. Close the control valve and open the valve on the cylinder.

6. Carefully balance the scale with the machine and the cylinder of sulfur dioxide, after all connections, including the discharge pipe, are properly made.

7. Place a one-pound weight on the platform of the scales. The purpose of this is to measure the time required to run out the first pound of sulfur dioxide.

8. Note the exact time. Open the control valve until the gauge registers the pressure which the test run has shown will cause the sulfur dioxide to flow at the proper rate.

9. Watch the scale and when it returns to balance, showing that one pound of sulfur dioxide has been used, note the exact time. For usual treatment the one pound should run out in exactly one minute. If less than a minute was required to run out the pound reduce the pressure slightly by means of the control valve. If more than one minute was required the pressure should be slightly increased. If the time actually required varied far from one minute the second pound should be timed. To measure the second pound another one-pound weight may be placed on the scale and the time again noted for the scale to come to balance.

10. Set the sliding weight on the graduated arm of the scale back exactly 10 pounds from its original position. Remove from the scale the one-pound weights used in timing the flow.

11. Allow the machine to run until the scale comes to balance, showing that 10 pounds of sulfur dioxide has been used. The 10 pounds should have been delivered in 10 minutes.

12. Close the control valve. Allow the pressure on the gauge to drop to zero and then immediately turn off the blower. Close the valve on the cylinder.

13. Close the ventilators on top of the car. Remove the false door from the car and close the side door tight. This completes the operation. The car doors should remain closed at least an hour and need not be opened at all unless samples are needed for examination or analysis.

SUGGESTIONS AND CAUTIONS

This process has been carefully worked out and the machines using liquid sulfur dioxide have been carefully standardized. The soundness of the fundamental principles of the process and the accurate workmanship put into the machines will not, however, compensate for ignorance nor carelessness on the part of the operator. A carload of grapes has an intrinsic value of over one thousand dollars. It can be totally ruined in thirty minutes by overdosing with sulfur dioxide. Therefore, while sulfur dioxide is a wonderful help in delaying the spoiling of the grapes, it is also a dangerous and

very expensive plaything in the hands of an irresponsible person. No one should attempt to treat a car of grapes until he has made himself thoroughly familiar with the principles of the process and the details of handling the particular machine he is contemplating using. It is suggested that one man be detailed to study the machine and operate it throughout the season.

Chemical Analysis and Test Boxes.—It is highly desirable to have chemical analysis made on samples taken from the first few cars of all different lots treated so that a check can be obtained on the amount of absorption obtained and the manner of treatment varied so as to meet the requirements of later shipments. This is the means of avoiding undertreatment, or overtreatment with resultant damage. The determination of the amount of sulfur dioxide in the grapes is not difficult nor tedious but a chemist is required to do it. The analysis must be made soon after the samples are taken, for the sulfur dioxide disappears very rapidly from the grapes. In no case should more than 24 hours elapse between treatment and analysis.

If the services of a chemist cannot be obtained, the next best thing is to place a box of test grapes in the center of the car. The box of test grapes is placed in the bracing at the center and the car treated. The car is allowed to remain closed at least one hour and then the test grapes removed. The test grapes are examined and tasted to determine whether their color, texture, or flavor has been injured.

Choice of a Machine.—The sulfur burner can be used only where power and running water are available and even then it is not recommended where either of the machines using liquid sulfur dioxide can be obtained and the liquid is not prohibitive in price. Its particular place is in regions where either the machines themselves or the liquid sulfur dioxide cannot be readily obtained. It does good work cheaply but is cumbersome and troublesome to operate.

The Type 1 liquid-using machine can be satisfactorily used anywhere that the liquid can be obtained. It requires neither power nor running water. The Type 2 machine can be used anywhere that electric power and liquid sulfur dioxide are available.

Opening the Ventilators on Top of the Car.—The immediate object of blowing the diluted sulfur dioxide into the car is to displace the air originally there and surround the grapes with a uniform dilute sulfur-dioxide–air mixture from which they can absorb the preservative. Obviously the original air cannot be driven out and displaced if the ventilators and the doors are closed. If they are left closed a

high back pressure is built up at the discharge and proper dilution of the gas prevented. The flow of gas remains constant and it is the air flow that is reduced. Consequently a much higher concentration of gas occurs in the center of the car and the grapes surrounded by this concentrated gas are ruined through overdosing.

Noxious Nature of Sulfur Dioxide.—While not intensely poisonous, sulfur dioxide is very irritating to the membranes of the eyes, nose, throat, and lungs. Breathing it results in a stinging, choking sensation which is very unpleasant. Hence all possible precautions should be taken to avoid unnecessary releasing of the gas, especially inside of buildings. A considerable part of the gas escapes from the ventilators while the grapes are being treated. At present no practicable means of avoiding this is known.

Refilling Cylinders with Liquid Sulfur Dioxide.—When small service cylinders are refilled from large supply cylinders they must not be filled full. The cylinders are intended to hold a definite quantity and only that quantity should be put into them. The cylinder being filled should rest on a scale so that the amount being put into it can be readily ascertained. If the cylinders are entirely filled with cold liquid, the liquid will expand, and perhaps burst the cylinder, when it gets hot. The closely confined liquid expands upon heating with an almost irresistible force. If a gas filled space is left in the cylinder the liquid has room to expand and the pressure increases but slowly with a rise in temperature.

Modifying the Concentration of Gas.—The rate at which grapes absorb sulfur dioxide varies with the concentration of the gas and the temperature, degree of maturity, and physical condition of the grapes. The usual procedure whereby the air in the car is displaced with a 2 per cent mixture of sulfur dioxide and then the doors closed is adequate for most grapes. Occasionally, however, conditions are met with under which too much or too little absorption of the preservative is obtained. Where these conditions can be recognized the usual procedure should be modified accordingly. The easiest and most practical means of modification with any of the three machines described is to change the concentration of the gas in the atmosphere used to displace the original air in the car. With the sulfur burner this is accomplished by using fewer or more pans in the burner. The Type 1 liquid-using machine is provided with interchangeable parts in the mixer which effectively accomplishes it. With the Type 2 machine it is accomplished by decreasing or increasing the pressure at the nozzle, as shown by the pressure gauge, according to whether a more diluted

or more concentrated mixture is desired. A flow of one pound in 70 seconds produces a 1.8 per cent mixture and of one pound in 50 seconds produces a 2.5 per cent mixture. The limits recommended to cover all conditions are a minimum of 1.8 per cent (by volume) and a maximum 3.0 per cent (by volume). The minimum should be used for grapes which absorb the preservative very rapidly, as for example underripe, and hot grapes, such as are often encountered in the very early regions of California and Arizona. The maximum should be used only on overripe, sound, cold grapes. Between these two extremes, all conditions are met with and unless tests, supported by chemical analysis, show modification to be advisable it is best to stay fairly close to the standard procedure, modifying the concentration only to allow for differences in the rate of absorption due to differences in maturity and temperature of the grapes. If the grapes are underripe (20° Balling or less) and warm, reduce the concentration to about 1.8 per cent. If the grapes are very ripe (above 25° Balling) and cold, increase the concentration to about 2.5 per cent. These directions are safe but never should the concentration be increased above 2.5 per cent except where experience or tests, supported by chemical analysis of the grapes, show it to be necessary. It is better to err on the side of undertreatment than overtreatment.

Treating Grapes in Storage Rooms or in Chambers other than Standard Refrigerated Cars.—The methods described in this circular have been worked out primarily with the idea of treating grapes after they have been loaded into iced refrigerator cars for shipment. If the conditions of treatment are essentially different the method must be modified accordingly. The proper modifications can only be determined by experiment but certain rules and suggestions can be formulated.

If the room is dry, or if it is cooled by means of dry cold pipes a lower concentration of gas should be used. Instead of the usual 2 per cent mixture used on grapes in refrigerated cars the concentration should be reduced to about 1.8 per cent (by volume). The room should be provided with ventilators or outlets at the top. The grapes should be stacked in the room in a manner similar to that used in loading a car. Also, the proportion of grapes to space should be similar to that of a car (30,000 pounds of grapes in about 2500 cubic feet). If these conditions exist the method of treatment need not be modified except as to concentration of sulfur dioxide in the air. Where conditions other than these exist and no means are at hand to determine the proper modifications to be used, it is probably best not to attempt treating the grapes at all.

Caution Against Treating Other Fruits.—Treatment of figs, cherries, and some other fruits with sulfur dioxide has been tried and the results have been very disappointing. The quantity necessary to repress decay in cherries and figs is sufficient to very seriously injure the color, texture, and flavor of the fruit. It is therefore recommended that the use of this process be confined strictly to grapes.

BENEFITS OF THE TREATMENT

The most important practical value of the treatment is the repression of the development of decay-causing organisms—chiefly molds—with the consequent lengthening of the keeping period. The preservative has the effect of decreasing the rate of activity of the normal life processes in the grape tissues and also reduces the tendency of the stems of the bunches to darken as they dry. These effects are, however, of small value in comparison with the benefits derived from the lessened rate of decay of the berries.

It is difficult to obtain the necessary quantity of data to enable one to evaluate the benefits of the treatment in commercial practice in terms of dollars and cents. Some treated grapes have been sold in the eastern markets at a premium of $0.50 per box (25 pounds) over similar untreated grapes shipped at the same time from the same vineyards and sold on the same markets at the same time. These were grapes which had been held for late markets and were slightly damaged by early rains. Other shipments of very good fruit earlier in the season showed little or no advantage of the treated fruit over the untreated. Still further on the other extreme are carloads which had been ruined by careless treatment whereby they had received far too much sulfur dioxide and were sold at a heavy discount or were condemned and not allowed to be sold at all.

The information gained during the past four seasons seems to indicate that the average benefit derived from the treatment of grapes to be shipped to eastern markets is between 10 and 15 cents a box. Greater benefits can be expected only from grapes which are unusually long in transit or from grapes which have been held for late markets and are not in prime physical condition although still of good appearance and free from obvious defects when shipped.

In no case is the condition nor the quality of the fruit at the time of treatment improved. Sulfur dioxide will not transform poor grapes into good grapes nor can it be considered in any sense a substitute for careful handling.